narrow bispinous diameter rather than the narrow bi-ischial diameter, since the spines being situated superiorly and posteriorly would present an obstacle to the rotation of the occiput before the pubic rami or the ischial tuberosities could exert their influence.

The above observations may have a very practical bearing on treatment. In occiput posteriors associated with a narrow bispinous diameter, intervention would be indicated earlier than under similar circumstances in a normal pelvis. In the former it would be questionable whether the usual policy of conservatism should be followed. If there is good evidence that the occiput is locked between the spines, that is, if the head is of average size or larger, is deflected and deeply engaged within a narrow bispinous diameter, it would be unwise to wait for signs of maternal exhaustion or fetal distress before intervening. Under such circumstances anterior rotation is unlikely to occur, and undue delay would merely result in impaction rendering manual or instrumental rotation difficult and version hazardous, not to mention the unnecessary suffering and the other well-known difficulties and dangers incident to a protracted second stage. These considerations are presented, not to encourage indiscriminate interference or a radical departure from well-established principles, but to point to a finer differentiation and selection of cases which may possibly lead to more rational management of the troublesome occiput posterior positions.

SUMMARY

The bispinous diameter was accurately measured in a series of cases. The data obtained show that the persistent occiput posterior position occurs almost invariably in pelves with a narrow bispinous diameter. The inference drawn from this observation is that the narrow bispinous diameter forms a serious obstacle to the cardinal movement of rotation. The practical bearing of this conclusion is the indication for earlier operative intervention in deeply engaged occiput posteriors occurring in pelves with a narrow bispinous diameter.

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CARBON DIOXID ABSORPTION FROM ANESTHETIC MIXTURES*

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THERE is no evidence that nitrous oxid gas enters into any chemical combination with body tissues when it is inhaled. This is probably true of other anesthetic gases, ethylene, for instance. Nevertheless, gases are habitually wasted in large quantities in order that the carbon dioxid exhaled by anesthetized patients may be eliminated into the atmosphere. In 1916 and following, numerous reports were made from the laboratory of Jackson describing various means of absorbing exhaled carbon dioxid from anesthetic gases and vapors. The first experiment made by Jackson and Mann was described as follows. Two dogs were placed in a gas-tight cabinet filled with twelve gallons of nitrous oxid. The contents of the cabinet were constantly pumped out through a solution of alkali which absorbed the carbon dioxid, then back into the cabinet. Oxygen was constantly liberated into the cabinet in small quantities. By this means the two dogs were kept anesthetized for twenty-four hours with the original twelve gallons of nitrous oxid plus sufficient oxygen to maintain metabolic activity.

Although there is no evidence that ether is chemically affected while producing anesthesia, it does tend to dissolve in the fats of the body to a greater and greater extent as the period of anesthesia is prolonged. There is, therefore, an apparent disappearance of ether from the circulation as it is dissolved out of the blood by lipoid tissue. As the ether comes back into the circulation during recovery, it leaves the blood through the alveoli and gradually, over a period of hours or days, is completely eliminated. Just as with the anesthetic gases, ether has been wasted to a large extent in that it had to be expired from an anesthetized patient in order to eliminate the carbon dioxid produced by that patient. The volatilization of ether has long been understood to take place more readily in the presence of a moderate amount of heat. The need for constant elimination of carbon dioxid has, however, made it impossible to satisfactorily warm inspired ether vapor by means of the patient's body heat. Many attempts have been made to warm ether vapor before it is delivered to the patient. Heating devices, however, have always been more or less unsatisfactory and dangerous because of the fire hazard. Heating devices may result in oxidation of ether, producing various impurities which are toxic. A closed system without exhalation valve permits the vaporization of ether in a warm medium due to the accumulation of body heat, but with the accumulation of body heat occurs an extensive unphysiologic accumulation of carbon dioxid, resulting in the necessity for its removal.

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By absorbing the carbon dioxid in soda lime, advantage may be taken of accumulated body heat to warm ether vapor. A reduction in body temperature has long been considered a possible accompaniment of protracted anesthesia. The demonstration, therefore, by Jackson of the feasibility of the removal of carbon dioxid produced by a patient in anesthesia through its absorption in an alkali, offered a means, not only of conserving anesthetic gases and vapor, but also conservation of the usually wasted heat and moisture lost through exhalation. In previous communications, attention has been called to the practicability of applying this principle, demonstrated by Jackson, to everyday use in operating room technique of inhalation anesthesia.

APPLICATION OF JACKSON'S PRINCIPLE TO PRACTICAL ANESTHESIA

Under ordinary conditions, the atmospheric space included in alveoli, bronchi, trachea, larynx, pharynx, mouth, nose and accessory sinuses is considered to constitute the respiratory tract. To apply the principle of Jackson to practical anesthesia, one must enlarge the normal respiratory tract to include a face mask and breathing bag. One should then make such an enlarged respiratory tract air-tight and fill it with anesthetic mixture suitable to a given individual. Such mixture may be one of nitrous oxid and oxygen, ethylene and oxygen, ether and air, or ether and oxygen, or any combination of these or other anesthetic agents. With this enlarged respiratory tract filled with an anesthetic mixture, the concentration of the anesthetic mixture containing oxygen, in the alveoli, and the mixture in the bag will be exactly the same with two exceptions. The alveolar content will carry an excess of carbon dioxid and the bag will contain an excess of oxygen. If such a closed respiratory tract is maintained in position for any length of time, the accumulation of carbon dioxid will increase throughout the system, always being high in the alveoli. Likewise the concentration of oxygen in the alveoli will tend constantly to be depleted and this depletion will affect the whole contents in a short time. No change will take place in the concentration of the anesthetic gas or vapor once equilibrium is established with the blood. In order, then, to make such enlargement of the respiratory tract filled with anesthetic mixture practicable for continuous maintenance of anesthesia, provision must be made for the removal of carbon dioxid gas, and for the addition of oxygen in sufficient quantities to replace that used from the blood by tissue metabolism. The most satisfactory means for the removal of carbon dioxid from this closed respiratory tract has been found, in our hands, to be the insertion of a quantity of high grade soda lime granules (sodium and calcium hydrate) as part of the system. The oxygen replacement can be best accomplished by constantly flowing into the system a steady stream of oxygen approximating the probable metabolic demand of the individual anesthetized. As anesthesia proceeds, fine adjustments of this flow of oxygen can be made to very closely approximate the amount of oxygen taken out by the blood during each minute of anesthesia. In this manner the blood is constantly supplied with a physiologic quantity of oxygen, and is relieved by the soda lime of its excess carbon dioxid in a physiologic manner without the development of hyperpnea or other disturbances of physiologic activity.

After a description of the technical means necessary for forming an enlarged respiratory tract, the various advantages of such a method of producing anesthesia by inhalation will be discussed.

TECHNIQUE OF ANESTHESIA

No effort will be made to carry the reader through the various experimental trials necessary to come to the realization of a practical equipment. Suffice it to say that attempts were made to apply Jackson's principle by means of closed circle devices through which the anesthetic mixture was made to circulate in one direction either because of one-way valves, or forced to circulate by means of an electric pump. The conclusion was reached that much more physiologic conditions could be maintained by inserting a soda lime canister between the face mask and the breathing bag, being sure that the openings in the soda lime container and bag were of sufficient size to avoid the possibility of interference with free breathing. In the accompanying illustrations are shown various types of mask and laryngeal airway through which air-tight connections can be made with a canister of soda lime granules and

TABLE 1.—*Gas Analyses**

	CO_2			O_2		
	Pharynx	Lips	Bag	Pharynx	Lips	Bag
No. 7416, after 35 minutes	4.8%	....	0.0%	27.2%	....	38.0%
No. 7891, gas-oxygen after 60 minutes	6.4%	4.2%	0.2%	9.8%	12.3%	22.4%
No. 9690, after 20 minutes systolic 155 and hyperpnea due to failing soda lime	....	....	9.6%	....	....	....
No. 9690. Same case 30 minutes later with fresh soda lime. Systolic 105. No hyperpnea	3.5%	2.9%	0.2%	8.3%	....	23.2%

* Gas analyses showing concentration of carbon dioxid and oxygen in various portions of the enlarged respiratory tract during anesthesia with absorption technique.

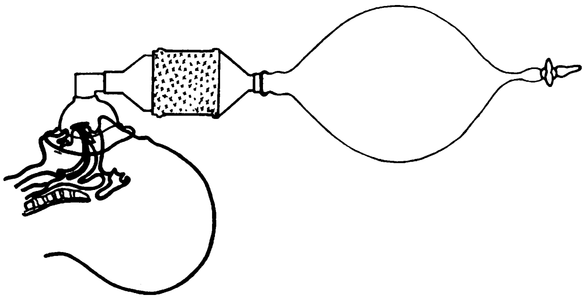

Fig. 1.—Diagrammatic sketch of enlargement of respiratory tract, consisting of pharyngeal airway, face mask, soda lime canister, and breathing bag.

breathing bag. It will be noted that in each one of these masks or airways there is provided an inlet nipple for the addition of a constant flow of oxygen as well as to make provision for an increase of anesthetic mixture to fill the enlarged respiratory tract either in the beginning of anesthesia or when a change is being made from one agent to another. The inlet serves its purpose best when situated proximal to the canister of soda lime rather than when connected with the breathing bag. This improvement in the technique was suggested by Guedel.

Whatever mask is used, it must be one capable of at least approximating an absolutely air-tight contact. The canister connects to the mask and to the breathing bag by means of metal slip joints. The cylindrical canister, measuring 8 by 12 centimeters, contains five hundred grams of high-grade soda lime granules 4 to 8 mesh, sold under the name "Wilson Soda Lime." There are many cheaper grades of soda lime available, and many other sized granules, but we have seen no preparation of soda lime as safe or satisfactory as the 4 to 8 mesh Wilson Soda Lime. If other sized granules are to be used, a modification would necessarily have to be made in shape and size of the canister. The total weight of canister and granules is nine hundred grams. The breathing bag found most convenient has been one of seven to ten liters capacity, light weight rubber. Smaller bags are usable, but less convenient. The substitution of a spirometer for the breathing bag has been made with considerable satisfaction, and will be the subject of another communication. It will be noted that no mention is made of an exhalation valve. There is none. When it is desired to empty the system, the mask is raised from the face during exhalation. All joints and connections of the apparatus, including contact of mask with the face, must be absolutely air-tight insofar as this is possible. As in all other inhalation anesthesia, care must be taken to insure an absolutely free airway to and from the deeper portions of the respiratory tract. The use of artificial pharyngeal airways or laryngeal airways (endotracheal) has been found convenient and physiologically beneficial. These pharyngeal and laryngeal airways will be seen in the accompanying illustrations, and are, we believe, self-explanatory. The gas control apparatus is that in ordinary use, with one exception, although it may be made much simpler. Means must be afforded for a finer measured constant flow of oxygen, capable of adjustment to slight variations. The quantities usually used of constant oxygen flow vary from one hundred to one thousand cubic centimeters per minute, the average being two hundred to four hundred. Only occasionally are wider variations in constant use of oxygen found. It will be noted that the masks and airways illustrated will provide varying amounts of dead space between the mouth or nostrils and the soda lime. This variety of masks and airways is provided to afford control of carbon dioxid conservation as well as to suit the requirements of different surgical procedures. A patient coming to the operating room with considerable respiratory depression due to the previous administration of nonvolatile anesthetic agents may require more conservation of carbon dioxid than one who has had no such medication. If further "piling up" of carbon dioxid seems advisable, the slip joints by which the canister of soda lime is held in place provide a means of connecting the mask directly to the bag, thus allowing the complete conservation of expired carbon dioxid over whatever period the anesthetist deems necessary to re-establish physiologic conditions.

CONDUCT OF ADMINISTRATION

By the description of an actual case, we can perhaps best explain the manipulation of this apparatus for the production of anesthesia. The soda lime canister is first taken in the hand and the lips placed in an air-tight manner in contact with one end, the other end being closed by the palm of the hand. By blowing into the canister

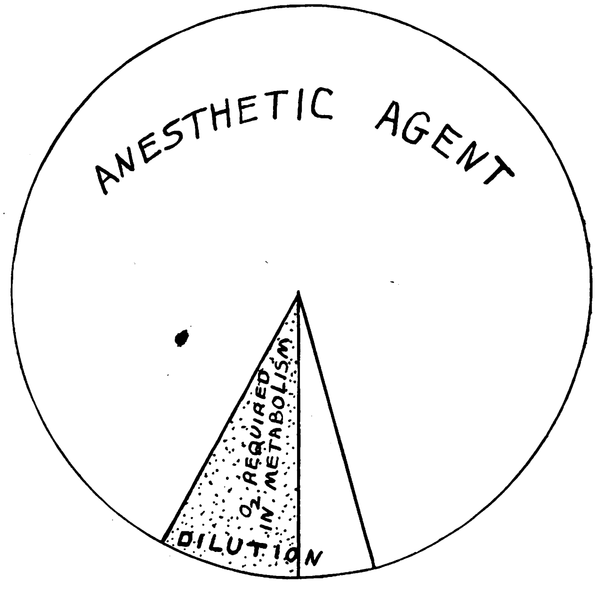

Fig. 2.—Respiratory tract must contain a mixture of anesthetic agent diluted sufficiently to suit each individual patient. Oxygen may serve as diluent. Percentage dilution varies widely for different patients with the same agent. Oxygen required for metabolism varies widely for each patient, but is apt to be nearly a fixed amount per minute for a given patient whatever the agent. This "metabolic" oxygen should be added by constant flow throughout anesthesia.

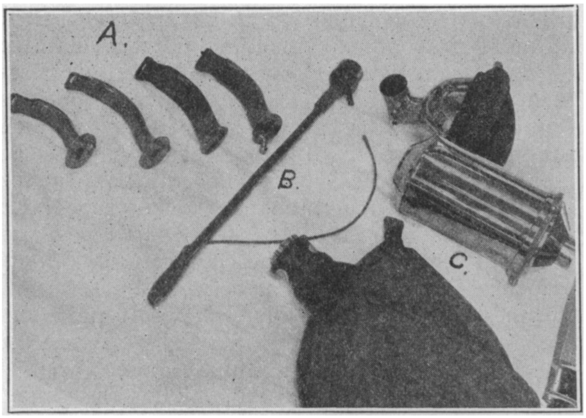

Fig. 3.—A. Variety of pharyngeal airways. B. Endotracheal airway with inflatible cuff to insure air-tight contact with tracheal mucosa. C. Mask, canister of soda lime, and breathing bag with slip-joint connections.

until considerable pressure has developed, and with the sudden release of the pressure when the hand is removed, any possible dust contained in the soda lime will be forced out. This process may be repeated if necessary. The canister is then placed on the anesthetist's table. The mask with a well-inflated face cushion is next connected to the inlet tubing from the gas apparatus. The breathing bag is connected directly to the mask by means of the slip joint, using a twisting motion always in connecting and disconnecting metal slip joints. A rapid flow of nitrous oxid and oxygen is started into the mask. The proportions of nitrous oxid and oxygen are usually those which the anesthetist presumes will approximate an anesthetic mixture for this particular patient. The mask is brought near enough to the anesthetist's face to assure him that no mistake has been made in connecting his gas tanks, and the mask is placed over the patient's face. It need not be held exceedingly tight at first until anesthesia has developed. As soon as unconsciousness appears, the elastic retaining device shown in the illustration is brought into place. This aids somewhat in relieving the muscles of the anesthetist's left forearm which would otherwise be kept at constant tension to maintain an air-tight contact. Nitrous oxid need be left running only so long as is necessary to fill the breathing bag. At the same time, the rapid flow of oxygen is discontinued and a flow which is thought to approximate the metabolic need of the particular individual (perhaps two or three hundred cubic centimeters per minute) is maintained. If ethylene is to be used, a replacement of the nitrous oxid with this gas is made as soon as unconsciousness has supervened. If nitrous oxid only is to be used, a fresh supply should replace the first bagful soon after unconsciousness is present. The first bagful is emptied by pressing on the bag and raising the mask slightly from the face during expiration. This replacement is necessary in order to eliminate as much as possible the residual nitrogen contained in the blood and respiratory tract before induction. Several replacements of the original gas in the bag will prove beneficial for this reason. Always remember that when replacement is performed, excess oxygen over that constantly running into the mask will probably be necessary to dilute the bag contents to a proper anesthetic mixture. At a convenient time soon after anesthesia develops, a pharyngeal airway should be slipped in place at the slightest evidence of respiratory obstruction. This is accomplished by tilting the mask upward from the chin with contact at the nose as fulcrum. A rapid flow of anesthetic gas should be started just previous to raising the mask in order to prevent air entering the system.

One should always remember that oxygen serves two purposes in anesthesia. First, it must be present in sufficient quantity to supply the metabolic demands of the patient from minute to minute. It also serves, however, to dilute an anesthetic gas or vapor to a proper degree to maintain good anesthesia. In the case of particularly potent drugs such as acetylene, cyclopropane, or ether and chloroform vapor, a part of the dilution may be accomplished with air or nitrogen, but in the case of nitrous oxid and ethylene, their potency is such that usually a very small amount of oxygen in excess of that necessary to supply metabolic requirements is sufficient dilution to form an anesthetic mixture.

Once sufficient carbon dioxid has accumulated in the respiratory tract, including the mask and bag, to maintain active respiratory effort somewhat in excess of normal, one may insert the soda lime canister. This may be accomplished during the expiratory phase by pinching off the bag full

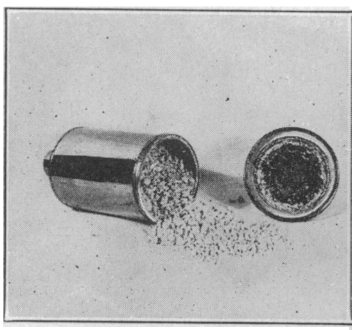

Fig. 4.—Canister of soda lime, open, showing granules.

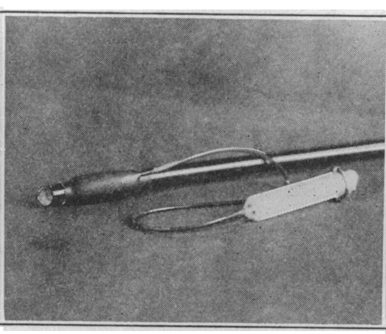

Fig. 5.—Detail of endotracheal airway, showing cuff inflated. Complete deflation is necessary during insertion and removal from trachea.

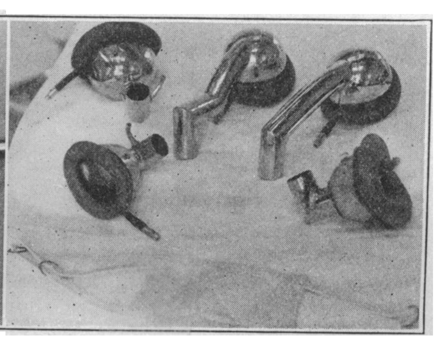

Fig. 6.—Assorted sizes and shapes of face masks. Canvas elastic retainer.

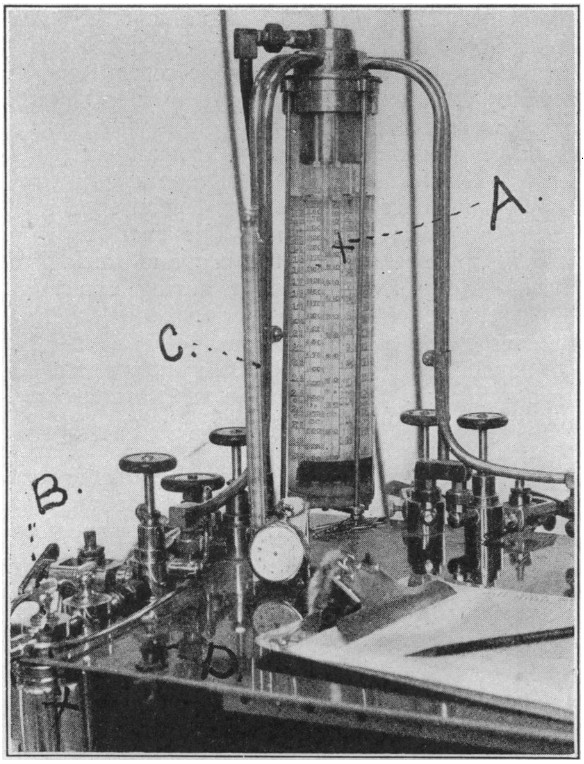

Fig. 7.—Combined anesthetic table and apparatus. A. Flow meters for various gases. Essential that meter for oxygen indicates slight differences in flow between 100 and 600 cubic centimeters per minute. B. Bottle for liquid agents which are volatilized by shunting part or all of oxygen flow through or over the liquid. C. Mercury column. D. Valve allowing compressed air or nitrous oxid to inflate blood pressure cuff.

of gas in the hand which disconnects the slip joint, or if deliberation is required in inserting the canister, a flow of whatever gas is being used may be started previous to making insertion of the canister and until it is in place. Once a proper anesthetic mixture occupies the respiratory tract, mask, bag, and canister, and the proper adjustment of the constant oxygen flow has been made to suit the metabolic needs of the patient, one may continue indefinitely with no further adjustments.

When evidence of too deep anesthesia is manifest by changes in physical signs, a rapid flow of oxygen into the mask through the delivery tube will allow of a single breath of an oxygen-rich mixture, thus quickly avoiding the development of unpleasant signs of overdose. If a quick return is made to slightly more than the previous flow of oxygen, the large excess of oxygen which the patient receives for one inhalation will be neutralized by the higher concentration in the breathing bag during the next respiratory cycle and so one will avoid the following advent of too light anesthesia. If the physical signs show evidence of too light anesthesia, a sudden puff of anesthetic gas through the inflow tube will correspondingly enrich the anesthetic mixture for one breath and this will again be neutralized in the following respiratory cycle. Thus the second to second control of anesthetic maintenance with gas anesthesia is more easily accomplished than with any other technique. In case of unexpected extreme respiratory depression or arrest, two procedures are available. First, tilting the mask away from the chin, accompanied by hand pressure on the bag, will quickly empty it while a rapid flow of oxygen has been instituted from the apparatus. As soon as there is any accumulation of oxygen in the bag, hand pressure will inflate the lungs. Second, if there is any doubt as to the oxygen supply in the apparatus, which is very often the case when need for chest inflation occurs suddenly during anesthesia, the best procedure is to disconnect the mask from the canister and blow directly into the mask. Such a procedure will avoid the possibility of a flustrated anesthetist losing valuable time in trying to adjust an apparatus which has already failed to deliver oxygen for one reason or another.

The only variation in this technique for use of acetylene, cyclopropane, and other more potent gases is that the original filling of the bag with these gases should be made with a greater flow of oxygen approximating a proper dilution to make a safe anesthetic mixture. The constant flow of oxygen necessary to maintain metabolism with the more potent gases, is similar to that necessary with ethylene or nitrous oxid. No work has yet been published to prove that metabolic rate is affected in different degree by different inhalation agents.

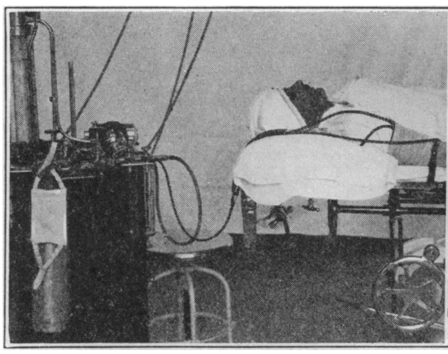

Fig. 8.—Full-sized pillow under patient's head and shoulders.

Fig. 9.—Head rotated to side (usually right) and retainer put in place before induction.

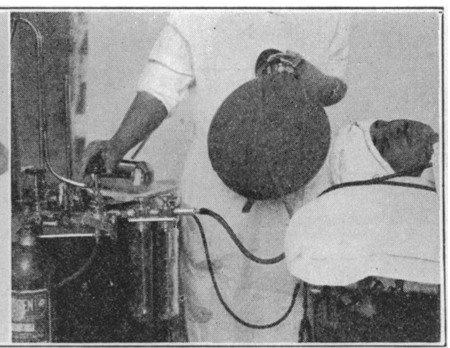

Fig. 10.—Soda lime canister has been freed from dust by blowing and lies ready. Breathing bag is attached directly to mask and filled with probable anesthetic mixture of nitrous oxid and oxygen. Note gas inlet is in mask.

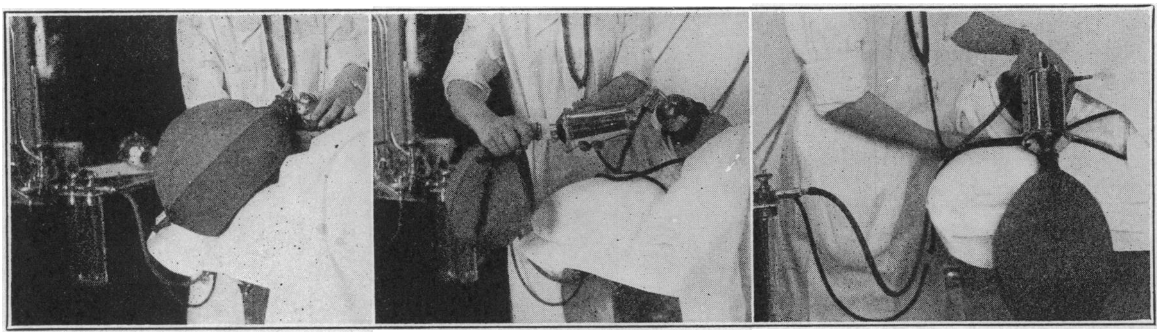

Fig. 11.—Induction, allowing accumulation of expired carbon dioxid. Oxygen, only, flowing from apparatus. Mask held by retainer.

Fig. 12.—Induction complete. Insertion of soda lime during expiratory phase of respiration. Alternative is reëstablishment of rapid flow of gas and oxygen from apparatus, allowing leisurely introduction of canister, since delivery tube enters mask.

Fig. 13.—Readjustment of head to maintain point of contact of canister with pillow as the fixed point; thus the weight of canister aids in retention of mask.

ADDITION OF ETHER

Small quantities of ether may be added to any gaseous mixture in this technique, either for a short time or throughout the anesthesia, by shunting the constant oxygen delivery through a supply of ether. Small quantities of ether will be found to accomplish the same result as much larger quantities of ether added to an open technique. If complete flaccid muscular relaxation is desired, it can be accomplished more satisfactorily with this technique and with less harm than by any other familiar to the author.

The procedure is as follows: Induction is made as described above, by filling the enlarged respiratory tract with a nitrous oxid-oxygen mixture, the soda lime canister being omitted until the required depth is reached. As soon as unconsciousness supervenes, a small amount (two hundred or three hundred cubic centimeters per minute) of carbon dioxid is run into the respiratory tract along with as large a supply of oxygen as is compatible with unconsciousness. As active hyperpnea develops, the oxygen and carbon dioxid flow is shunted through the supply of ether, vaporizing rather large quantities just short of that sufficient to cause irritation of the upper respiratory mucosa. If necessary, a slight flow of nitrous oxid may be added through the ether in addition to the oxygen and carbon dioxid. If the breathing bag becomes distended to some extent, so much the better. When a thoroughly active hyperpnea has developed, the carbon dioxid flow is cut off, but addition of ether is continued until the third plane of third-stage ether anesthesia is reached. This means passage through the second plane with an eyeball fixed on center (complete extrinsic ocular muscle paralysis) and on through delayed intercostal activity to complete intercostal paralysis which marks the entrance into the third plane. At this point, the soda lime canister is inserted, being careful to pinch off the breathing bag and not waste the accumulated gas and vapor therein. Throughout this procedure as high a content of oxygen has been maintained as possible. Only ether vapor and oxygen may fill the respiratory tract. The function of the nitrous oxid has been served, once unconsciousness has been accomplished and ether anesthesia induced. Slight distension of the bag is beneficial rather than harmful. When the third plane is reached (requiring three to ten minutes) the canister of soda lime is inserted. One may then allow the anesthesia to become slightly less intense, aiming at about the mid-region of the second plane. This depth of anesthesia produces a condition more satisfactory to the surgeon for abdominal work than is that of the third plane. In the third plane, diaphragmatic activity is increased to compensate for lack of thoracic breathing, and the resultant movements may be an embarrassment to the surgeon. Maintenance of this depth may or may not require a small constant addition of ether vapor. Such addition is accomplished, when necessary, by allowing the constant stream of oxygen which is added to maintain metabolic requirement, to

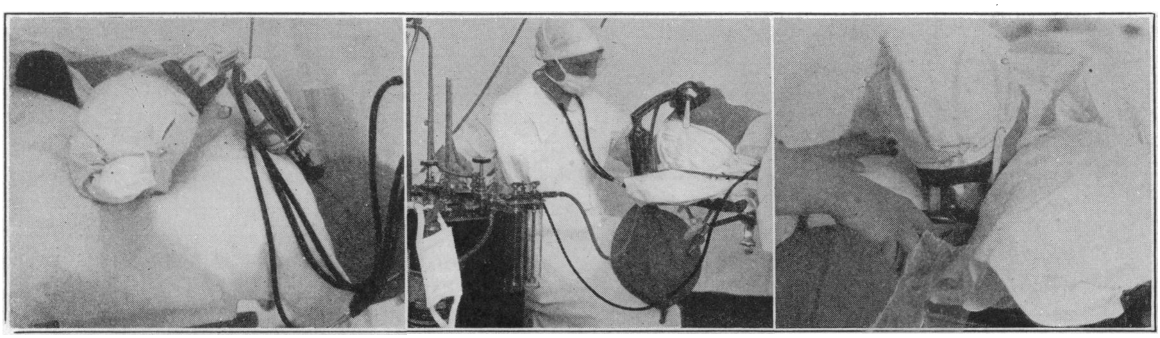

Fig. 14.—View from head of table.

Fig. 15.—Thyroid mask.

Fig. 16.—Prone position. Head rests in mask.

pass through or over the surface of the ether supply. The total quantity of ether necessary for the accomplishment of an hour's anesthesia with flaccid muscular relaxation need seldom exceed two ounces.

MASKS

By the use of various shaped masks, such as those illustrated, the convenience of the anesthetist and surgeon may be suited to the different positions necessary for the accomplishment of many surgical procedures. For the accomplishment of head surgery of various sorts, the application of closed endotracheal airways to the technique as described elsewhere is found most convenient. The method implies a completely controlled and free airway down to and including the larynx. The enlargement of the upper respiratory tract to include mask or airway, soda lime canister and breathing bag, must constitute an entirely leak-proof space to obtain the best satisfaction. The accomplishment of a leak-proof system and a free airway is not difficult in the hands of the experienced anesthetist.

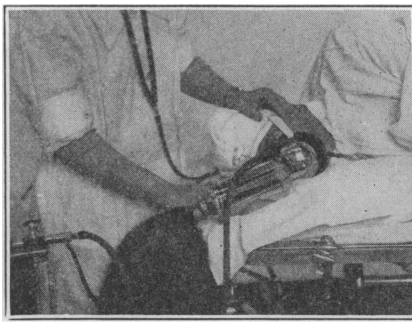

Fig. 17.—Lateral position.

Fig. 18.—Air-tight endotracheal airway. Canister and bag may be carried to either side or down along chest. A towel may be clamped around canister and to pillow or patient's shirt, after patient is in final position for operation.

COMMENT

Temperature.—Some methods of inhalation anesthesia have long been considered likely causes of a reduction in body temperature. The tendency with this technique is toward a rise in body temperature rather than a fall. The warm atmosphere leaving the alveoli during each respiratory cycle passes out through the soda lime, where the carbon dioxid which it contains is left as a carbonate and this same atmosphere again enters the lower respiratory tract during the next respiratory cycle. The constant flow of oxygen in the mask has replaced the oxygen absorbed from it during the previous respiratory cycle. There is a tendency to the production of heat in the mass of soda lime because of the chemical reaction by the carbon dioxid and hydroxid to form carbonate. This added heat proves to be a benefit to the patient. The objection has been raised that too great a heat might develop in the respiratory tract as a result of the chemical reaction. With some grades of soda lime, a damaging concentration of heat might possibly occur, but with the high-grade soda lime above mentioned, we have found it impossible to develop, in the atmosphere inhaled by the patient, a temperature higher than forty degrees centigrade. In the center of the mass of soda lime, a temperature as high as forty-seven degrees has been noted during clinical anesthesia, but the atmosphere is cooled enough as it passes from the soda lime toward the trachea so that even forty-seven degrees never reaches the mucous membrane of the air passages. There can be no fear of damage from excessive heat with this temperature. In this connection, it must be remembered that if one adds pure carbon dioxid to the system with the soda lime in place, a much more rapid chemical reaction will take place in the soda lime with corresponding excessive development of heat. We have found it possible to reach a temperature, in the center of the soda lime mass, of one hundred degrees centigrade when pure carbon dioxid was circulated through it. It is therefore not advisable to make a practice of adding carbon dioxid to the enlarged respiratory tract when the soda lime canister is in place. It should be removed if high concentrations of carbon dioxid are to constitute the respiratory atmosphere.

It is our belief that the respirations during inhalation anesthesia conducted by this technique much more nearly resemble those of normal sleep than when similar drugs are inhaled in any other manner. Possibly the maintenance of the inspired atmosphere at body temperature is a factor in accomplishing this result. There is a tendency to an increase in general body temperature as observed with a thermometer in the axilla or in the rectum rather than toward a decrease.

Moisture.—Very early during anesthesia conducted by this technique the enlarged respiratory tract is filled with atmosphere completely saturated with moisture. During prolonged anesthesia, the cooling effect of the room atmosphere outside the breathing bag may result in some condensation of moisture in the breathing bag. The quantity of water, however, which is actually lost from the patient's circulation in this manner is very slight even through a long anesthesia. All inhalations consist of a completely saturated atmosphere. Since dehydration is one of the unphysiologic accompaniments of inhalation anesthesia, we believe that the constant inhalation of a saturated atmosphere with a minimum loss of water from the body by exhalation is of decided physiologic benefit. There is another very definite advantage to the administration of anesthetic mixtures containing 100 per cent relative humidity. Ether vapor, and ethylene and acetylene gases in the presence of high relative humidity are less of a hazard from the standpoint of explosion and fire. We therefore feel that the technique is well worth while from this standpoint alone. The usefulness of these drugs is too great to discard them for no other reason than fear of explosions.

Control.—Many anesthetists have felt, on first attempting the technique, that the fine control of oxygen supplied to the patient, and of carbon dioxid elimination, was interfered with as compared with other techniques with which they were familiar. Further experience, however, has convinced them that the matter of fine control rests largely in the hands of the anesthetist and his complete familiarity with whatever technique he chooses to employ. Since Guedel has suggested the inlet source for oxygen being placed between the soda lime canister and the patient, we have experienced no difficulty in regard to quick and minute control of the depth of anesthesia and oxygen supply. Open techniques may attempt to give a graduated variation of rebreathing with the view to individualizing the carbon dioxid output for each patient according to his physiologic requirements at the time of anesthesia. The practical results of such attempts, however, have fallen short of the ideal expected. The ease with which the canister of soda lime may be removed in the technique herein described, thereby allowing an entire accumulation of the expired carbon dioxid for whatever period seems necessary, takes care of gross abnormalities of physiology occurring during administration. The capacity of the usual adult mask is 350 cubic centimeters, and the accumulation of carbon dioxid to the extent involved in this dead space will usually approximate that necessary to maintain normal respiratory minute volume when administration is superimposed upon premedication with sedative drugs. In the case of children and in some unusual circumstances, the use of smaller masks or the connection of pharyngeal and laryngeal airways direct to the soda lime canister improves the character of the breathing, bringing it to a more physiologic level. If one appreciates the two functions of oxygen in anesthesia, one to dilute the anesthetic agent to make of it a proper anesthesia mixture for each patient, and the other that of supplying oxygen for the metabolic activities of the body, we believe that the control of anesthesia and the maintenance of physiologic conditions of respiration is more easily accomplished by this technique than by those in general use.

Quantity of Agents.—It will scarcely be appreciated by the uninitiated how small actual quantities of anesthetic gases and oxygen are necessary for the maintenance of anesthesia by this technique. If care is used in avoiding waste, a gallon and a half of nitrous oxid for induction, two gallons of ethylene for maintenance, and one gallon of nitrous oxid during recovery may be made to suffice for an anesthesia of any length whatever. Once the enlarged respiratory tract is filled with a proper anesthetic mixture, and the oxygen adjusted to the metabolic requirements of the patient, anesthesia may be conducted without further addition of ethylene even though the anesthesia may be hours in duration. This fact seems quite incomprehensible to the average anesthetist at first thought. It can be accomplished in every case if the anesthetist will take pains to establish at the very beginning of anesthesia an absolutely free airway and an enlarged respiratory tract completely free from leaks. As previously mentioned, two ounces of ether vaporized is sufficient for the maintenance of the most profound relaxation in laparotomy. The advantage here is twofold. First, no ether vapor contaminates the atmosphere inhaled by the surgeon and anesthetist; and second, two ounces can be eliminated in a very short period postoperatively, whereas eight or ten ounces of ether will need a much longer period for elimination. The danger of saturating the atmosphere of the operating room with a highly concentrated mixture of air and ethylene or other explosive gas or vapor is very much reduced. If the anesthetist will take care that his machine is leak-proof, and that the contact of mask and face is tight, no hazard is run by the use of actual cautery in the operating room. Anesthetists have long been embarrassed by the necessity for a choice of agents in a given case on the ground of expense to the patient. The closed technique herein described makes the use of expensive gases no more costly than is an ordinary open ether administration which has often been used as a basis of estimate for the comparative cost of anesthesia. The small total quantity of gases coming in contact with the patient may avoid severe intoxication under certain circumstances. For instance, an eighty-gallon tank of ethylene was once used by the writer to anesthetize twelve different individuals. The tank was afterward found to be contaminated with carbon monoxid in sufficient quantities, so that had the eighty gallons of ethylene been used to anesthetize one patient, as would have been the case by the use of any other technique, sufficient carbon monoxid poisoning would probably have taken place to have resulted in the death of the patient. This accident actually happened to two patients anesthetized by ethylene from the same lot. Finally the total weight and bulk of gases and apparatus necessary for the accomplishment of a morning's work in anesthesia is reduced from a truckload to the contents of a handbag or, at most, two small handbags.

There are certain intangible effects of anesthesia which can only be described as disturbances of physiology. Perspiration, mucous secretion, abnormalities of respiration during anesthesia and similar disturbances following anesthesia with the addition of nausea, vomiting, chills, and many other unpleasant after-effects have all appeared to us to be less frequent than before this technique was instituted. In a word, the sum total results have seemed to be more physiologic.

Bacterial Contamination.—It has been suggested that the danger of cross infections was enhanced. The mask is removed from the canister after each anesthesia and thoroughly washed with soap suds and hot water, rinsed in hot water and dried, unless a particularly dangerous case from the standpoint of infection has been handled, when further sterilizing procedures are instituted.

The canister containing soda lime granules may be autoclaved with surgical dressings if necessary. The breathing bag may be washed in alcohol, boiled, or otherwise sterilized. The possibility, however, of bacterial contamination was investigated by Dr. W. D. Stovall, director of the Wisconsin State Laboratory of Hygiene, and visiting bacteriologist at the Wisconsin General Hospital. His reply follows: "Complying with your request to carry out some bacteriological examinations to determine the probability of your anesthesia apparatus acting as an agent for conveying bacteria from one person to another, I have performed two sets of experiments. First, I poured a culture of staphylococcus into the canister containing soda lime. I then drew air, which was first washed through several washings of sterile distilled water, through the soda lime in the canister and through beef infusion glucose broth. This experiment I allowed to run two hours and at the end of that time the cultures were placed in the incubator for a period of a week. In no case did the culture show a growth of any kind. The other experiment was made by blowing air into a bottle containing a suspension of bacillus prodigiosis. The air was blown through this suspension of bacteria so that it agitated it and made a fine spray in the bottle. Through a small glass tube which reached just through the cork of this bottle, I drew air by a process of suction through the soda lime of the canister and then through glucose beef infusion broth. These cultures were also incubated for one week. None of them showed any growth. While this is a limited number of experiments, I consider that the apparatus was submitted to a very severe test and I believe that if the bacteria do not find their way through the canister into the media by these experiments, that there is certainly no possibility of bacteria being transferred from one patient to another by contamination of the lime in the canister." In order to completely cover this situation, Guedel has made it a practice to place mask, canister, and bag in a muslin container, autoclaving the container and contents after each anesthesia. From the standpoint of the "cleanliness appeal" to the patient, we believe this a good practice, although entirely unnecessary for the complete avoidance of cross infections.

Soda Lime.—The greatest difficulty which we have personally experienced with this method has been that in connection with the soda lime itself. Any attempt to use inferior grades of soda lime has always resulted in disaster. Smaller sized granules than 4 to 8 mesh are not applicable to the size canister here described. Handling of soda lime containers results in more or less dust formation in the soda lime. It is therefore advisable to buy original containers from the manufacturer with as little handling of the granules as possible before their use. The canister is filled with as little trauma to the granules as possible, the canister being tapped on the side as it is filled so that the granules completely fill the canister before the cover is screwed on. It will be noted that the cover is held in place by a threaded ring so that the whole top of the canister need not be turned, in forcing the cover down air-tight. After filling, any dust contained in the granules should be blown out either by means of compressed air or more conveniently by blowing into the canister, as already described. This procedure should be repeated before each anesthesia if any doubt exists as to the presence of dust. Soda lime dust is a mildly alkaline powder only slightly irritant to either the skin or mucous membranes of most individuals. There are, however, individuals highly susceptible to weak concentrations of alkali in which the presence of this dust in the conjunctiva, on the skin, or respiratory mucosa might result in irritation. With reasonable care, no dust need ever so contaminate the patient.

Renewal of Soda Lime.—The five hundred grams of soda lime contained in the canister is sufficient for the absorption of the expired carbon dioxid of a patient over a period varying from six hours to ten or twelve hours, depending on the size of the patients anesthetized and their metabolic rates. It has been estimated that an individual utilizes five to six cubic centimeters of oxygen per minute for each kilogram body weight. He will produce slightly less than this amount of carbon dioxid each minute. As one becomes more familiar with this technique, the variation both in the production of carbon dioxid and the consumption of oxygen with variations in metabolic rate will become evident. It is convenient to record the number of times that a given canister is used after filling, by means of a check mark on a small rectangle of adhesive plaster stuck to the cover of the canister. One need never fear the presence of saturated soda lime until the canister has been used at least six times. The presence of hyperpnea or other respiratory disturbance not explainable on other grounds may be taken as evidence of depleted absorptive qualities of soda lime. If in addition there is a gradual rise in systolic blood pressure occurring, one may test by expelling the contents of mask and bag by raising the mask and pressing on the bag during expiration, meanwhile allowing fresh gases to flow in. If the hyperpnea disappears and the systolic returns to normal with the display of fresh gases, the soda lime is saturated and should be replaced by a fresh canister.

Gas Analysis.—In the accompanying table are shown analyses of the contents of the enlarged respiratory tract from samples taken during clinical anesthesia. Samples have been taken from the region of the glottis in the pharynx, from the mask in front of the face, and from the breathing bag. As would be expected, there is a much higher content of oxygen in the breathing bag than in the mask or pharynx, and the reverse is true of the carbon dioxid concentrations. The samples shown in the table were taken with oxygen delivery made in the distal end of the bag instead of into the mask.

SUMMARY

This technique has been used for over ten years and is considered by the author to be the ideal means of controlling inhalation anesthesia. There

are now available at Wisconsin General Hospital records of five thousand cases anesthetized in this manner during the past four years. A similar number have been made by the author elsewhere. Our impression is as suggested above, that the results have been more physiologic than with other methods. The necessity for the use of an endotracheal airway for head work has left something to be desired in short operations of this sort. In operations about the head lasting longer than a half hour, we believe that the introduction of an endotracheal to-and-fro airway is indicated, and results in benefit to the patient. The complete absence of respiratory obstruction serves to protect the patient against circulatory damage from this cause. Short periods of respiratory obstruction may be tolerated, but over long periods, obstruction is damaging to even the best surgical risk. The cost of anesthesia by this technique has been greatly reduced and the absence of anesthetic gases and vapors in the atmosphere of the operating room has been greatly appreciated by the operating team. The fire and explosion hazard is greatly reduced, we believe. In the attempt to instruct others in the use of carbon dioxid absorption, we find them slow to appreciate its advantages in proportion to their familiarity with open techniques. The more experience an individual has had with open techniques the more difficult he will find it to acquire a conception of the two functions of oxygen in anesthesia. The experienced anesthetist in open techniques will also have a tendency to disregard leaks since by means of positive pressure from his apparatus he has been wont to counteract the effects of ill-fitting mask, etc., and has forced the gas outward through the poor contact to prevent the entrance of air. The slightest opening, which would not be considered a leak in any other technique, may make quite impossible the conduct of good anesthesia in the manner here described. There is a tendency to fail to appreciate the slighter degrees of respiratory obstruction. An absolutely free airway is essential to the conduct of physiological anesthesia.

It is believed that a stimulus to a better understanding of the physiology of respiration and circulation will come to the anesthetist who familiarizes himself with carbon dioxid absorption. A large field for physiologic investigation is made available. For instance, we know little of the effect on metabolic rate of the various anesthetic agents. With slight modifications of the above described apparatus, direct recorded readings of oxygen consumption during anesthesia can be made. Many refinements in technique suggest themselves, pregnant with practical advantages. A citation follows: If a flexible container is substituted for the breathing bag herewith illustrated, and its excursions graduated in cubic centimeters, one can record or read directly respiratory excursions and minute volume. By the addition of a mechanical trigger which is tripped when the enlarged respiratory tract begins to lose contents, one can arrange an automatic control of oxygen feed. Many other investigative and practical modifications and applications of the technique suggest themselves as one becomes familiar with it. The practical use of carbon dioxid absorption as well as its experimental availability for physiologic investigation, rests largely upon one's ability to eliminate leaks and the maintenance of absolutely free unobstructed movement of the atmosphere contained in the enlarged respiratory tract. A knowledge of the physiologic functions of carbon dioxid and oxygen and the ability to control these factors is essential to the anesthetist. Given the physiologic knowledge, he will find the control directly in his hands by the use of the technique above described and its many modifications.

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PENETRATING WOUNDS OF THE CHEST*

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PENETRATING wounds of the chest are not uncommon, but their severity varies greatly and the complications which arise from them constantly bring up new problems.

In civil life, trauma to the chest from gunshot and stab wounds and severe crushing wounds of the chest are the injuries seen most commonly. War injuries, with their large defects in the chest wall, retained foreign bodies in the lung or pleural cavity, and severe infection [1] constitute a somewhat different problem which we shall not discuss further in this paper.

COMPLICATIONS

Among the complications arising from penetrating wounds of the chest are open pneumothorax, closed pneumothorax, hemothorax, and hemopneumothorax.

Open Pneumothorax.—It was believed originally that an open communication between the thoracic cavity and the outside air was compatible with life only as long as that opening was smaller than the glottis. More recently Graham [2] has taken issue with this belief (rightly in our opinion), stating that the higher the individual's vital

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